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Tritiated D_2O Transport Container Closure Study

Report No 87-2-K

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Mechanical Research Department

ABSTRACT

A project aimed at improving the sealing gasket on the D_2O transportation container was undertaken for the Nuclear Materials Management Department. The purpose of the project was to determine why the original silicone rubber closed cell sponge gaskets leaked during a 22 psig hydrostatic pressure tests, and provide a solution. After determining the cause of leaking, different gasket materials were investigated and solid silicone rubber was chosen as the new gasket material. A silicone rubber gasket was tested and found to pass hydrostatic pressure and helium leak tests successfully. The effect of cutting and splicing the new silicone rubber gasket back together again was also investigated. The repaired gasket was found to perform well as it again passed a hydrostatic pressure test and held up well during a helium leak test. It is concluded that, in the configuration tested, solid silicone rubber is a suitable gasket material for sealing against water at pressures of up to 22 psig in the D_2O transport container.

job	file	date	report no.
21-111-462	825.17	March 16, 1987	87-2-K

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EXECUTIVE SUMMARY

Tritiated D_2O Transport Container Closure Study

R. Zane

A project was undertaken for the Nuclear Materials Management Department, to improve the sealing gasket on the D_2O transportation container. The gasket seal, located between the container's lid and body, leaked during a 22 psig hydrostatic pressure test performed on a full-scale model of this container.

The purpose of the program was to determine why the gasket seal leaked and to provide a solution to the problem. To accomplish this, a model of the D_2O container sealing arrangement was built. The model simulated actual container conditions and enabled hydrostatic pressure and helium leak tests to be performed on various gaskets.

The original sealing gasket was made of soft silicone rubber closed-cell sponge. The gasket tested was exactly the same except that the manufacturer made it with a dimpled backing. It is believed that this gasket leaked because the sealing pressure between gasket and gasket seat wasn't enough to flatten the dimples. An intimate seal was, therefore, never achieved. A new gasket material was, therefore, investigated.

Solid silicone rubber was chosen as the new gasket material. A solid silicone rubber gasket was tested and successfully passed a 24 hour, 22 psig hydrostatic pressure test with no leakage. The gasket also performed well in a helium leak test.

The final test in the program involved cutting the silicone rubber gasket and splicing it back together again. The gasket was then tested once more using the same hydrostatic pressure and helium leak tests. The spliced gasket passed the hydrostatic pressure test and performed well on the helium leak test as shown

	Unspliced	Spliced
leak rate	3.0×10^{-5} std cc/sec	5.0×10^{-5} std cc/sec

The "spliced " "unspliced" data were required by the Nuclear Materials Management Department to determine if the gaskets could be manufactured in segments (as opposed to complete units) and whether emergency "on-site" repairs could be performed.

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Mr. H.N. Isaac
Nuclear Materials Department
Design & Development - Generation

Tritiated D_2O Transport Container
Closure Study

1.0 INTRODUCTION

A project was undertaken for the Nuclear Materials Management Department to improve the existing gasket seal on the D_2O transportation container. The gasket seal located between the container lid and body, had leaked during a 22 psig hydrostatic pressure test performed on a full scale model of this container. It is essential that this seal be leak proof to prevent any loss of D_2O during transportation.

The purpose of the project was to determine why the existing gasket seal failed and to provide a solution to the problem. To accomplish this, a test rig which modelled the sealing arrangement of the D_2O container was designed and constructed. The test rig enabled hydrostatic pressure and helium leak tests to be performed in the laboratory on various gaskets.

The original D_2O container gasket was made of soft silicone rubber closed cell sponge. A new gasket of this material was first tested in the testing rig. After analyzing its performance, it was decided that a new gasket material was required. The selection of the new gasket material was based on results obtained from two separate compression tests. In these tests, a sample of gasket material was compressed and allowed to freely expand radially. The same sample was then placed in a restraining jig and compressed again. The jig restrained the sample's radial expansion under compression providing compressibility data of the gasket material. These tests showed that solid silicone rubber was a suitable new gasket material. A gasket was made and subsequently tested in the test rig.

Following the tests described above, the same silicone rubber gasket was cut, spliced back together and tested once more. This was to investigate the effect of the splice on the gasket's sealing performance. The data from this test was required in order to determine if the gaskets could be manufactured in segments as opposed to complete units and, whether emergency "on-site" repairs could be performed.

2.0 TEST RIGS

The test rig used to perform the hydrostatic pressure and helium leak tests is shown in Figure 1. The rig consists of two 762 mm diameter plates made from 1 1/2" thick aluminum. The two plates are held together by twelve 1" bolts which pass through both plates. The base plate is geometrically a full-scale replica of the sealing arrangement found on the D_2O transportation container. A round 7 mm deep recess was machined in the center portion of this plate such that when the top plate is bolted in place, an inner volume is defined. The top plate is just a round flat plate which serves as the rig's lid. Pressurization and depressurization of the inner volume was achieved via the two access ports drilled through each plate (Refer to PROCEDURE section).

The specimen restraining jig shown in Figure 2 was used to perform the restrained compression tests. The jig consists of a die with a precisely machined 1.1284 inch diameter blind hole and a cylindrical 1.1160 inch diameter punch (Refer to PROCEDURE section).

3.0 TEST PROCEDURES

3.1 Hydrostatic Test

In this test, the gasket was mounted in the test rig and the rig's inner volume filled with water to a pressure of 22 psig. The pressure and rig were then monitored for any pressure loss and visual signs of leakage for a 24 hour period (see Figure 3).

3.2 Helium Leak Test

The helium leak test involved placing the test rig inside a plastic covering which was subsequently inflated with helium. A vacuum was then drawn inside the rig volume and the total helium leakage into this volume was monitored for a 40 minute period using a helium leak detector (see Figure 4).

3.3 Compression Tests

Two types of compression tests were performed; unrestrained and restrained. In both tests, a round material specimen having a nominal cross-sectional area of one square inch was used.

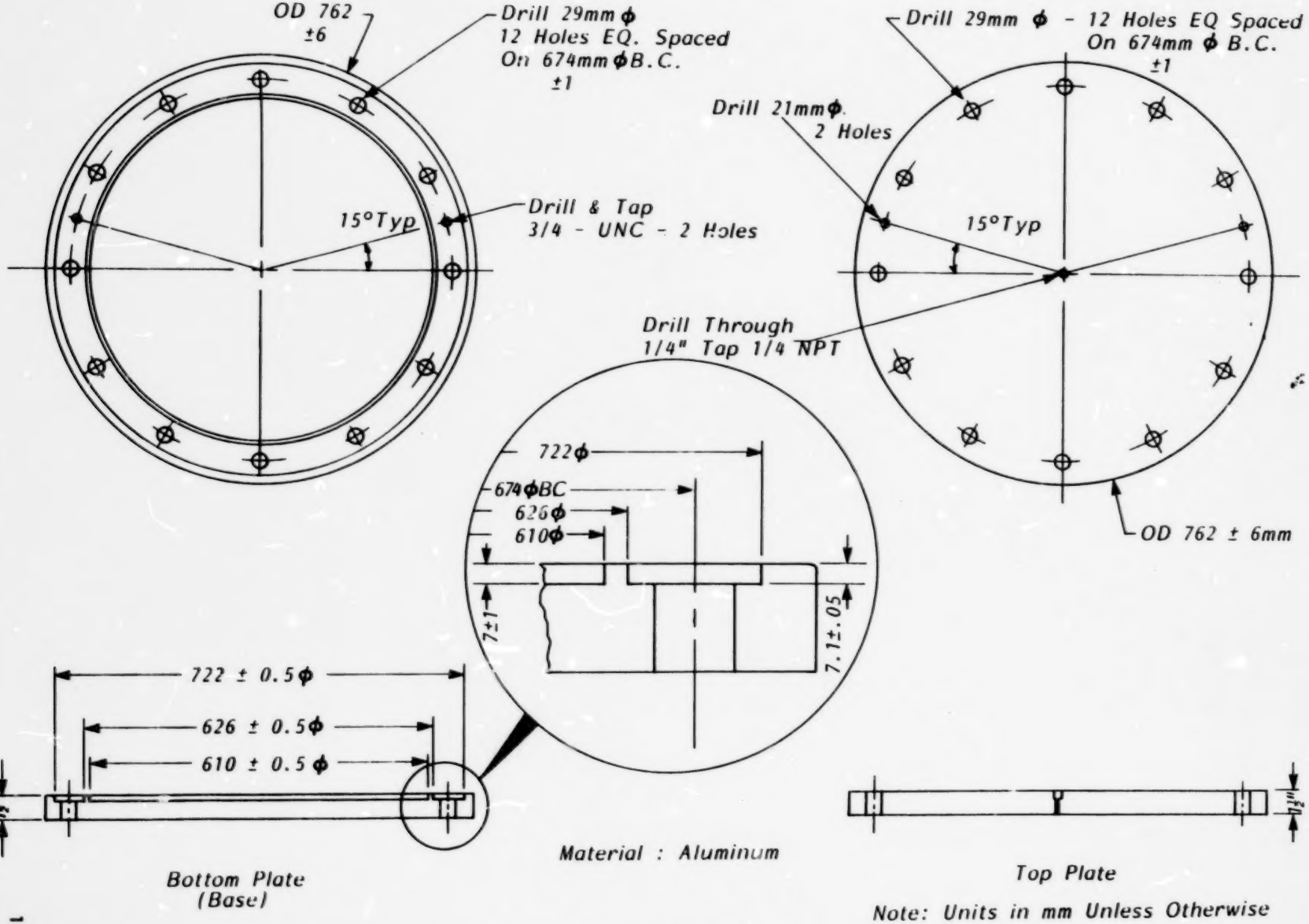


FIGURE 1

TRITIATED HEAVY WATER TRANSPORT CONTAINER GASKET TESTING RIG.

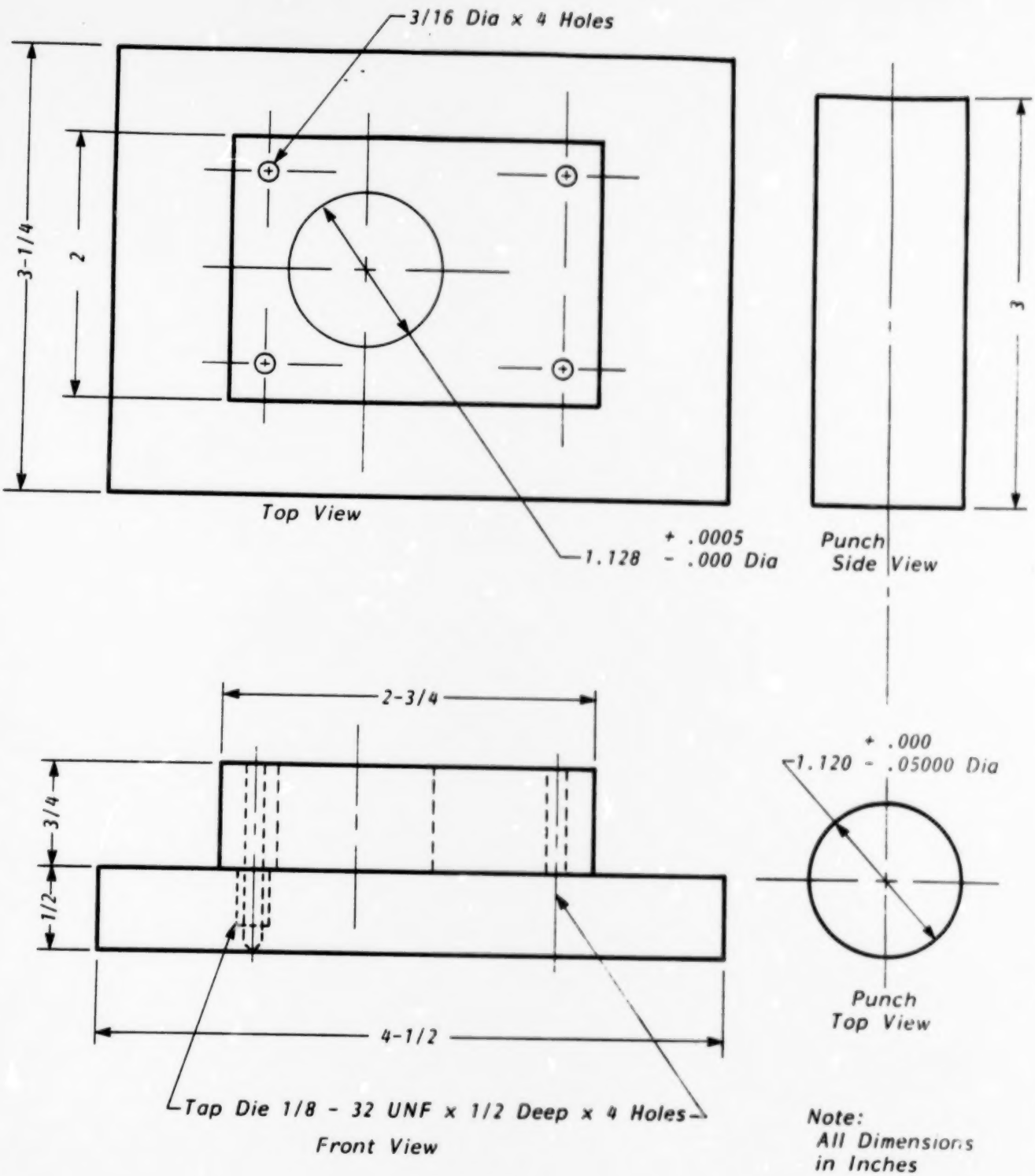


FIGURE 2
SPECIMEN RESTRAINING JIG

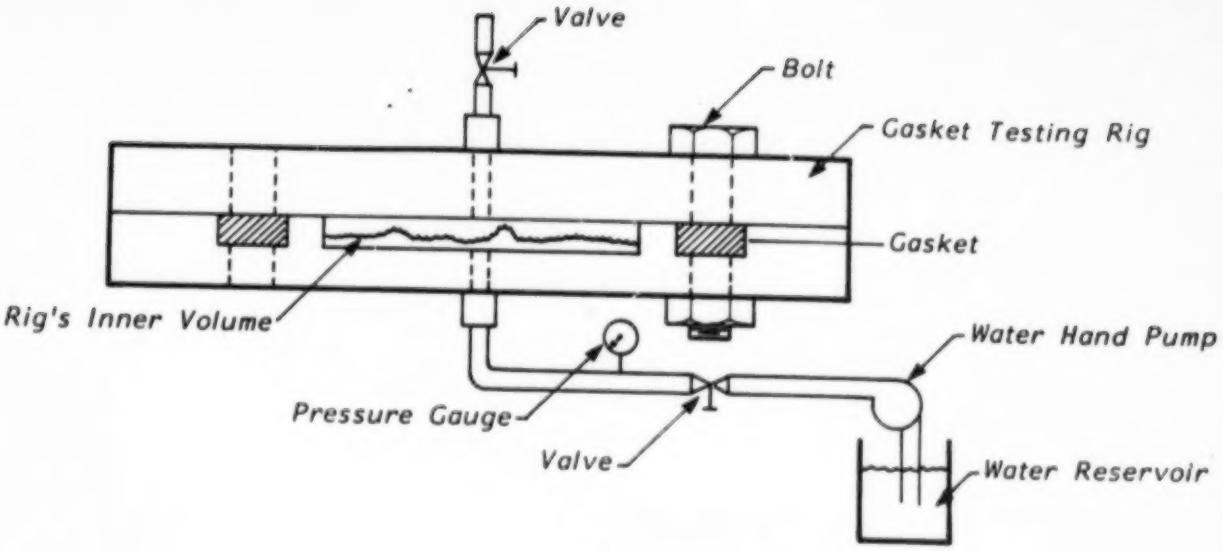


FIGURE 3
HYDROSTATIC PRESSURE TEST

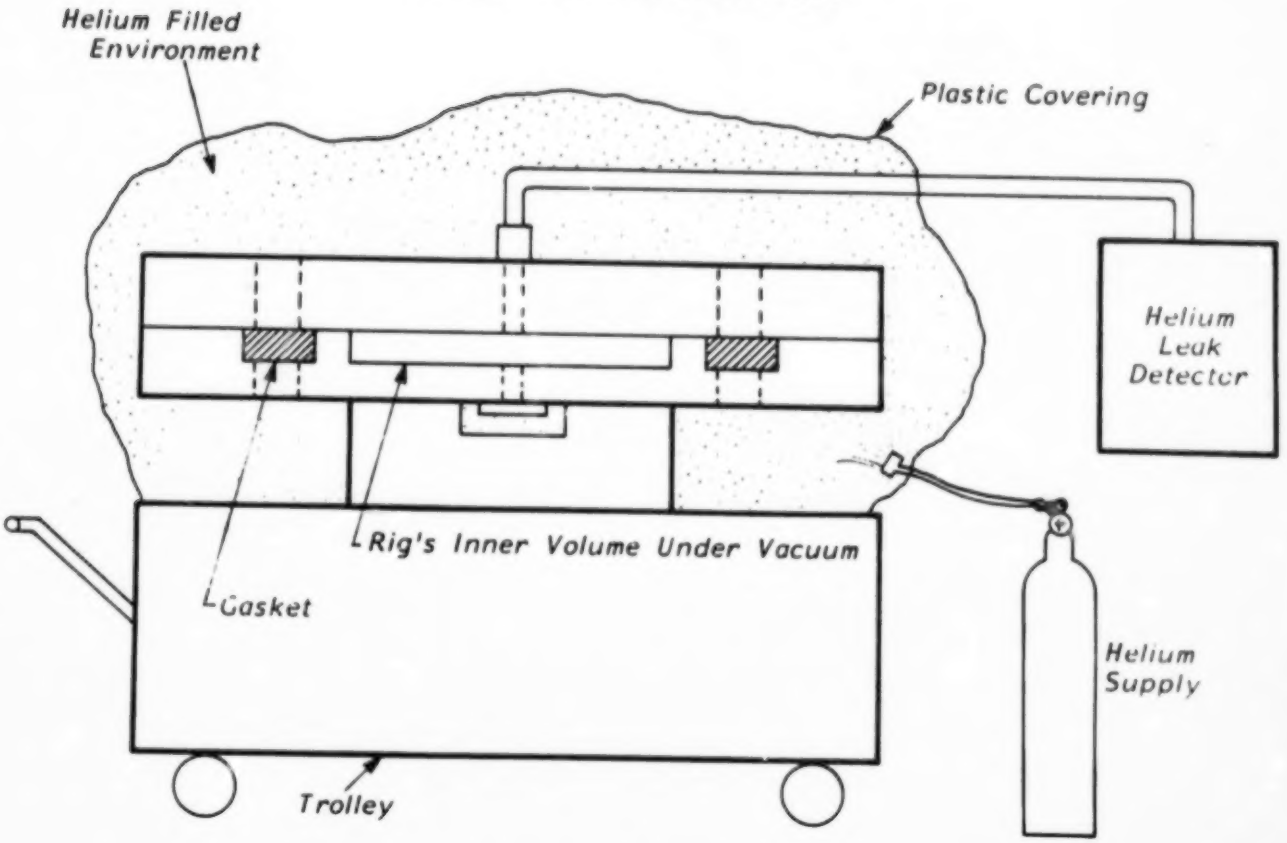


FIGURE 4
HELIUM LEAK TEST

In the unrestrained test, the material specimen was placed under the cross-head of a standard universal testing machine and continuously compressed.

In the restrained test, the material specimen was inserted into the die of the restraining jig and slowly compressed by having the universal testing machine push down on the punch as shown in Figure 5. The cross-sectional area of the die is also one square inch and, therefore, the material specimen fitted snugly and had no room to expand when compressed. As a result the load-displacement curves from this test indicate changes in the specimen's volume under specific loading conditions. The specimen's compressibility can, therefore, be calculated.

For both the unrestrained and restrained tests, the compressive loads on the specimen were 200 lbs and 500 lbs, carried out in two separate tests.

4.0 TEST RESULTS

4.1 Original Silicone Rubber Closed-Cell Sponge

The original D_2O gasket seal was made of silicone rubber closed-cell sponge, and had a smooth surface finish. For testing purposes a new gasket was ordered, but when it arrived it was found that for some reason the manufacturer had made the gasket with the stiff dimpled backing. This dimpled gasket failed the 24 hour hydrostatic pressure test. It began to leak around several of the rig's bolt holes before a 22 psi rig pressure was reached. An unrestrained compression test was performed on a sample of the gasket and produced the load-displacement curve shown in Figure 7. From this curve it was found that the sealing pressure between the gasket and rig body was approximately 15 psi. This pressure should be sufficient to produce a seal against 22 psi fluid pressure, however, a good seal was not obtained. It is believed that the gasket failed because the 15 psi pressure was not sufficient to flatten out the stiff dimples on the gasket backing. As a result a leak path remained. It is also felt that the width of the gasket between the bolt hole edge and the gasket inner diameter may not have been sufficiently wide. It would be desirable to have at least several cell thicknesses in this area to ensure that no leak paths existed from cell to cell. It is also possible that since this area was narrow, it was the weakest part of the gasket and so may have been deformed by the water pressure.

NOTE: Calculations of the gasket sealing pressures can be found in Appendix A.

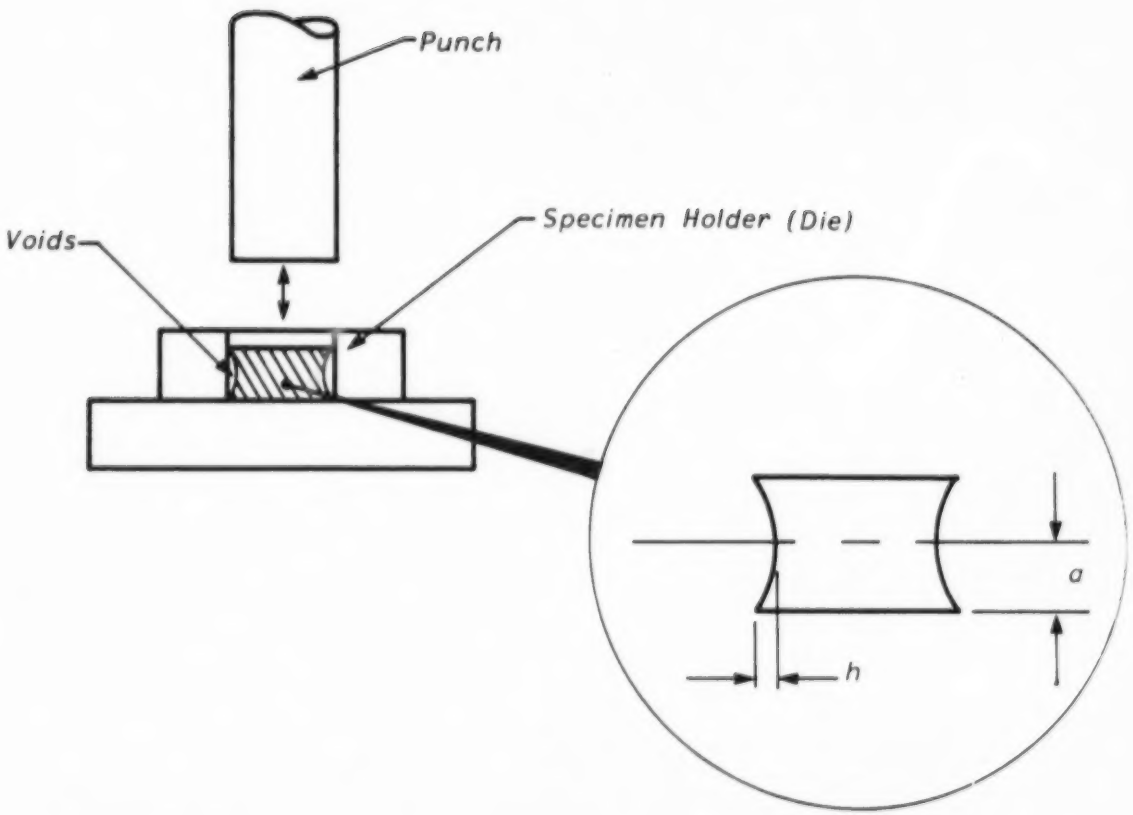


FIGURE 5
SPECIMEN RESTRAINING JIG

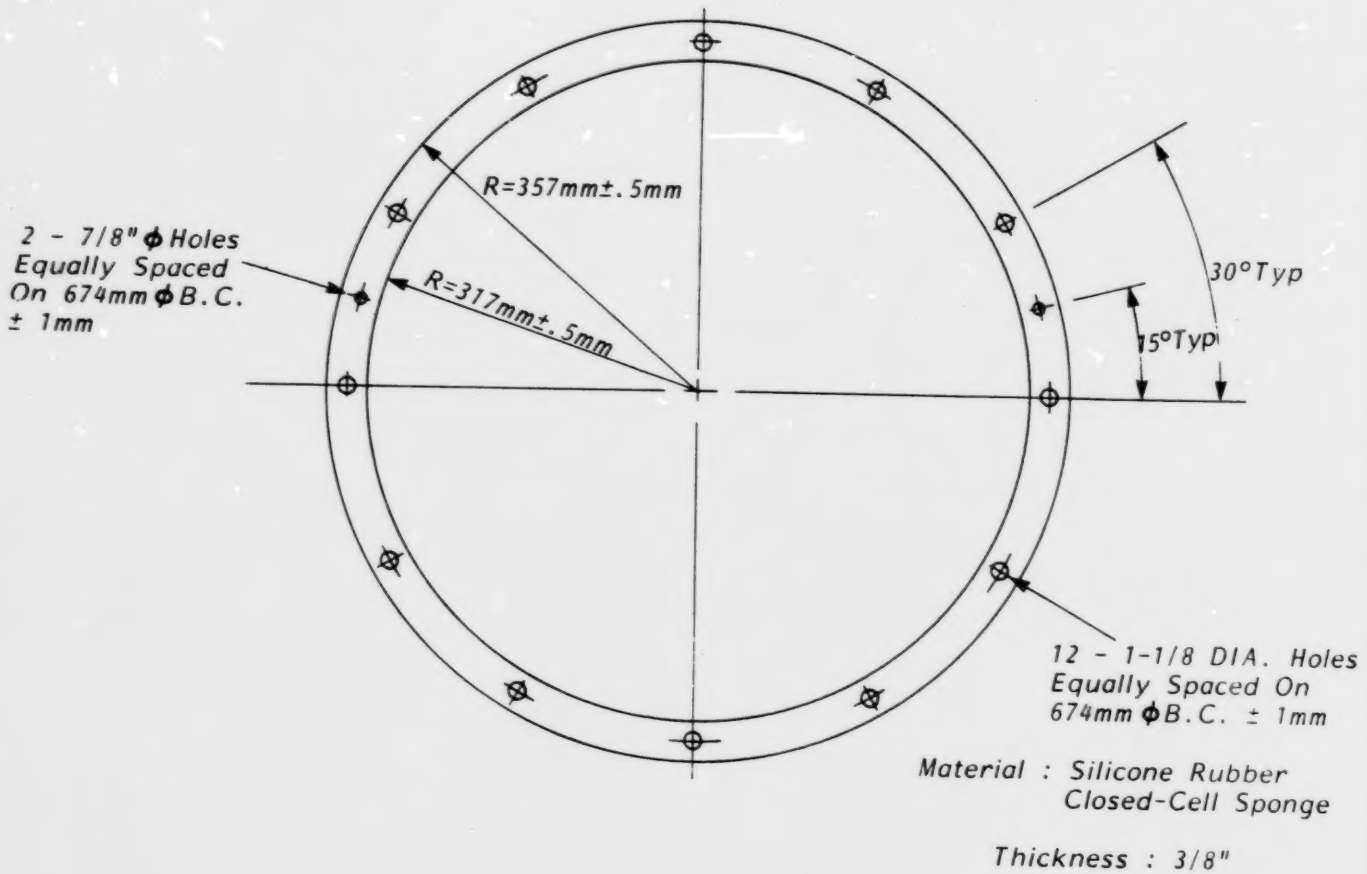
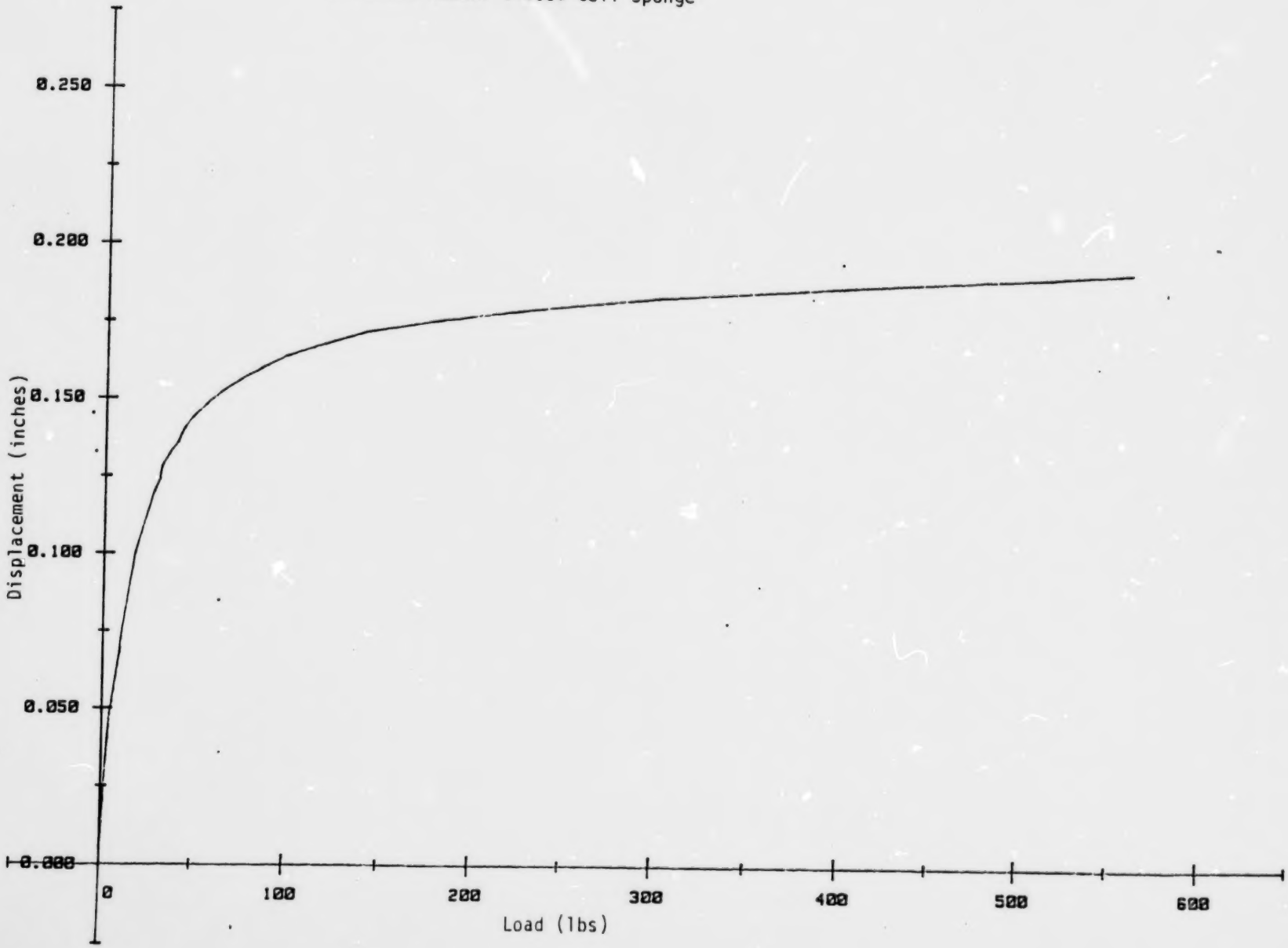


FIGURE 6

SILICONE RUBBER CLOSED - CELL SPONGE GASKET

FIGURE 7

Unrestrained Compression Test
Silicone Rubber Closed-Cell Sponge



4.2 Compression Tests on Solid Silicone Rubber Sample

Due to the previously discussed problems, solid silicone rubber was investigated as a possible alternative as a gasket material. The unrestrained compression test produced the curves shown in Figure 8. They indicated that a silicone rubber gasket designed as shown in Figure 9, would produce a sealing pressure of 164 psi in the test rig (see Appendix A). This pressure far exceeds the 22 psig required for proper sealing.

The restrained compression tests produced the load-displacement curves shown in Figure 10. The silicone rubber only compressed 3.25% of its original volume under a compressive load of 200 lbs and, 5% under a 500 lb load. This indicates that silicone rubber exhibits close to constant-volume behaviour (incompressible) under these loads. In fact, at the sealing pressure of 164 psig, the material's compressibility is only 1% of its original volume. Silicone rubber, therefore, would be a suitable gasket material providing that the gasket is sized to permit unrestrained lateral expansion in the gasket seat.

4.3 Hydrostatic Pressure and Helium Leak Tests on a Solid Silicone Rubber Gasket

4.3.1 Unspliced Gasket

This gasket passed the hydrostatic pressure test with no pressure loss or visual signs of leakage.

The helium leak rate was measured as being 3.0×10^{-5} std cc/sec.

4.3.2 Spliced Gasket

The gasket was cut and spliced back together again, using clear RTV silicone cement. It was cut at a 45° angle across its thickness, between bolt hole No 2 and No 3 (see Figure 11). After allowing 24 hours for the splice to cure, the gasket was again subjected to the hydrostatic pressure and helium leak tests.

The gasket passed the hydrostatic pressure test with no pressure loss or visual signs of leakage.

The helium leak rate was measured as being 5.0×10^{-5} std cc/sec.

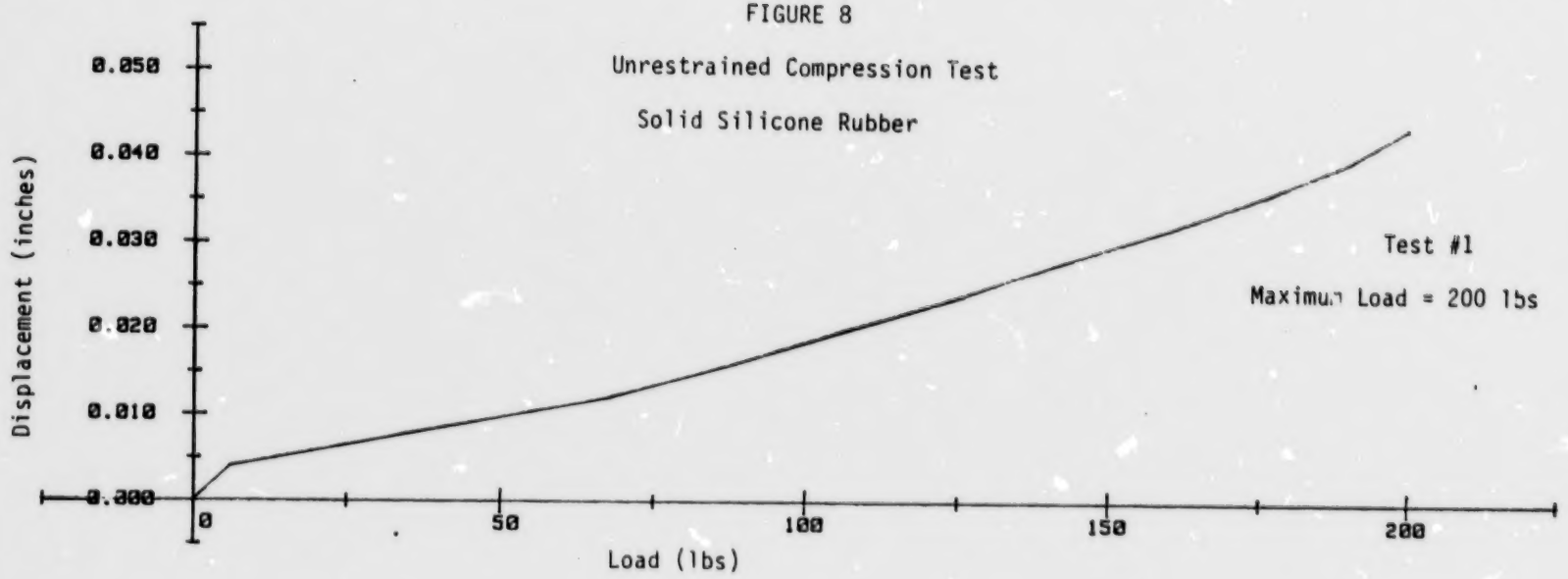
4.3.3 Analysis

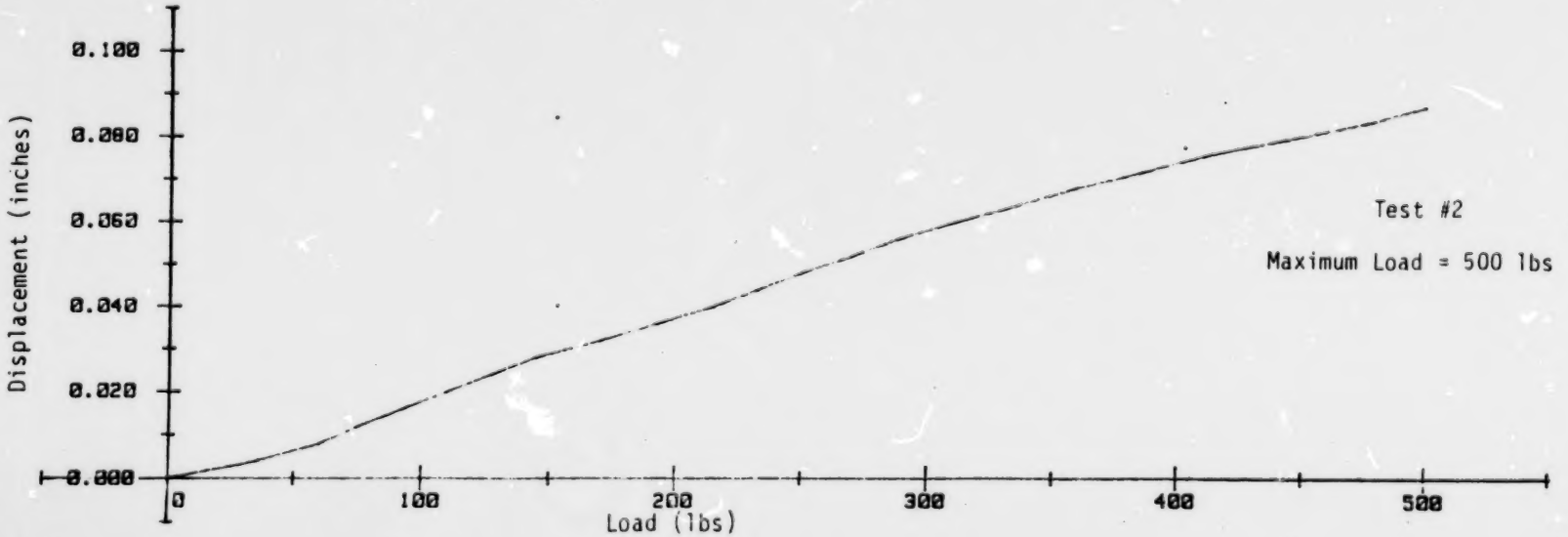
The slightly higher leak rate obtained with the spliced gasket was apparently due to the splicing operation. During this operation, some of the silicone cement was squeezed out over the top and bottom of the gasket. This occurred when the two ends of the cut gasket were brought together and pressure applied.

FIGURE 8

Unrestrained Compression Test

Solid Silicone Rubber





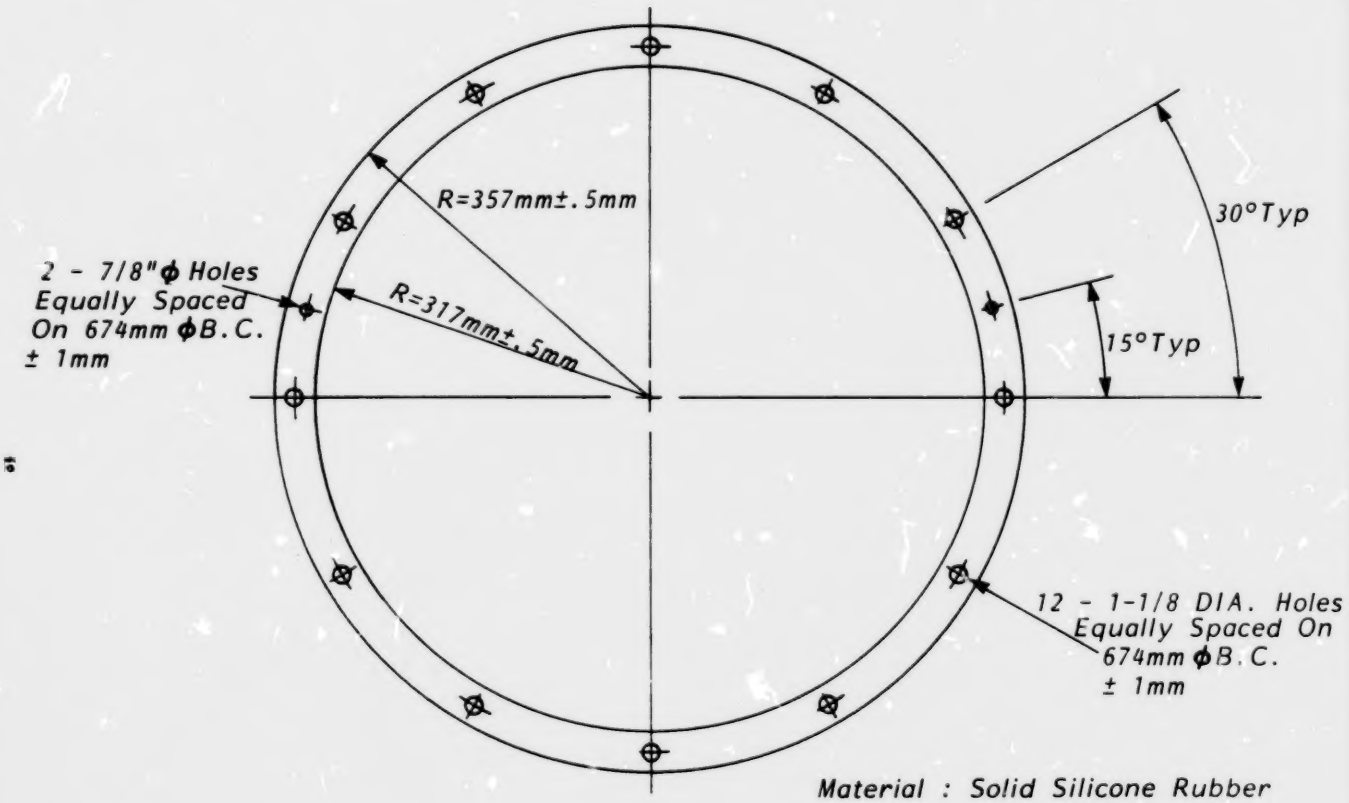


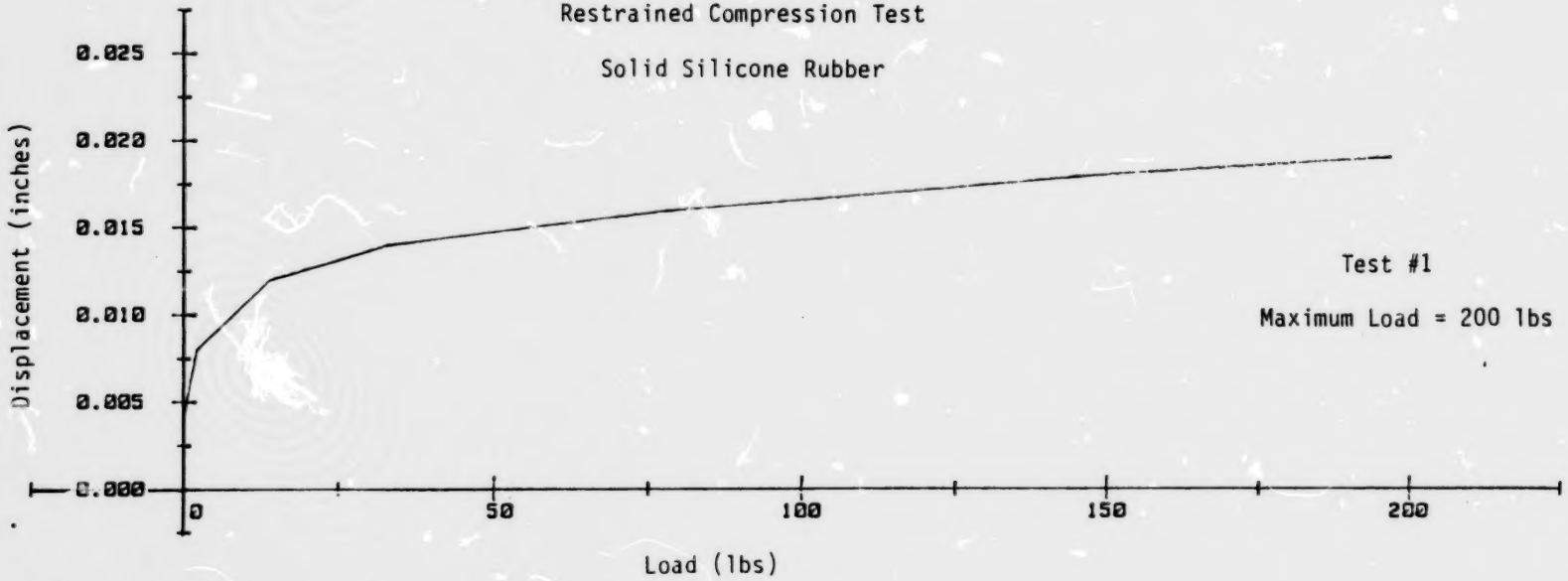
FIGURE 9

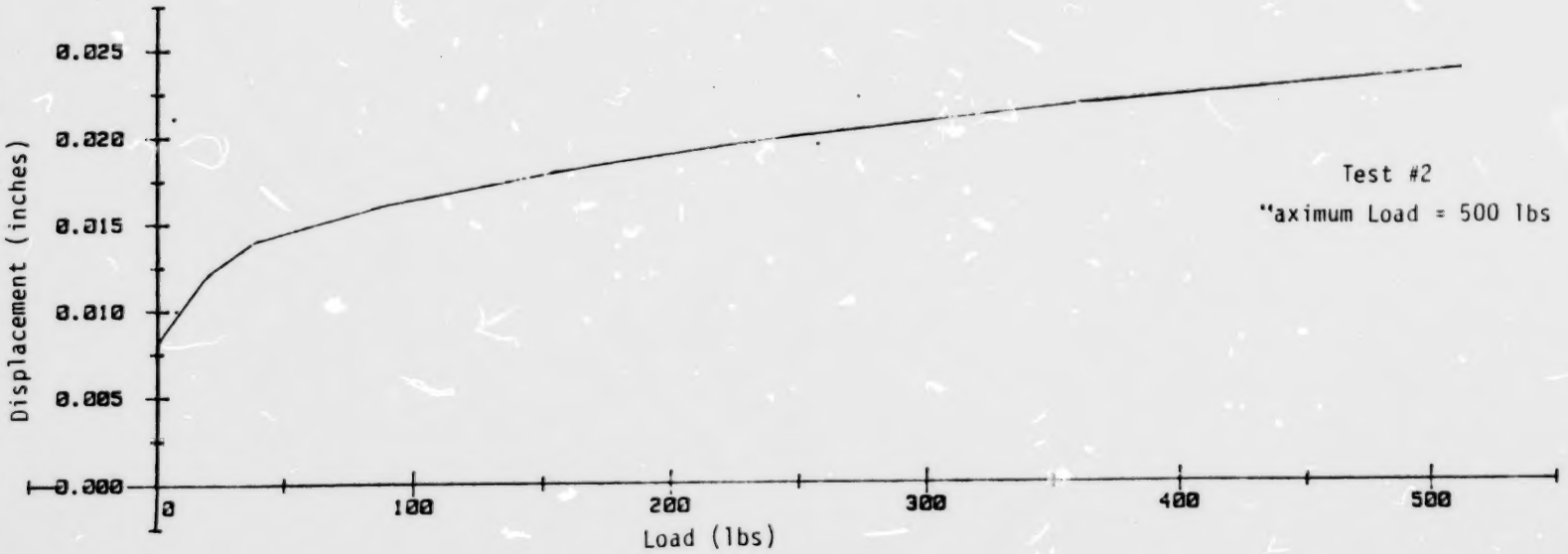
SOLID SILICONE RUBBER GASKET

FIGURE 10

Restrained Compression Test

Solid Silicone Rubber





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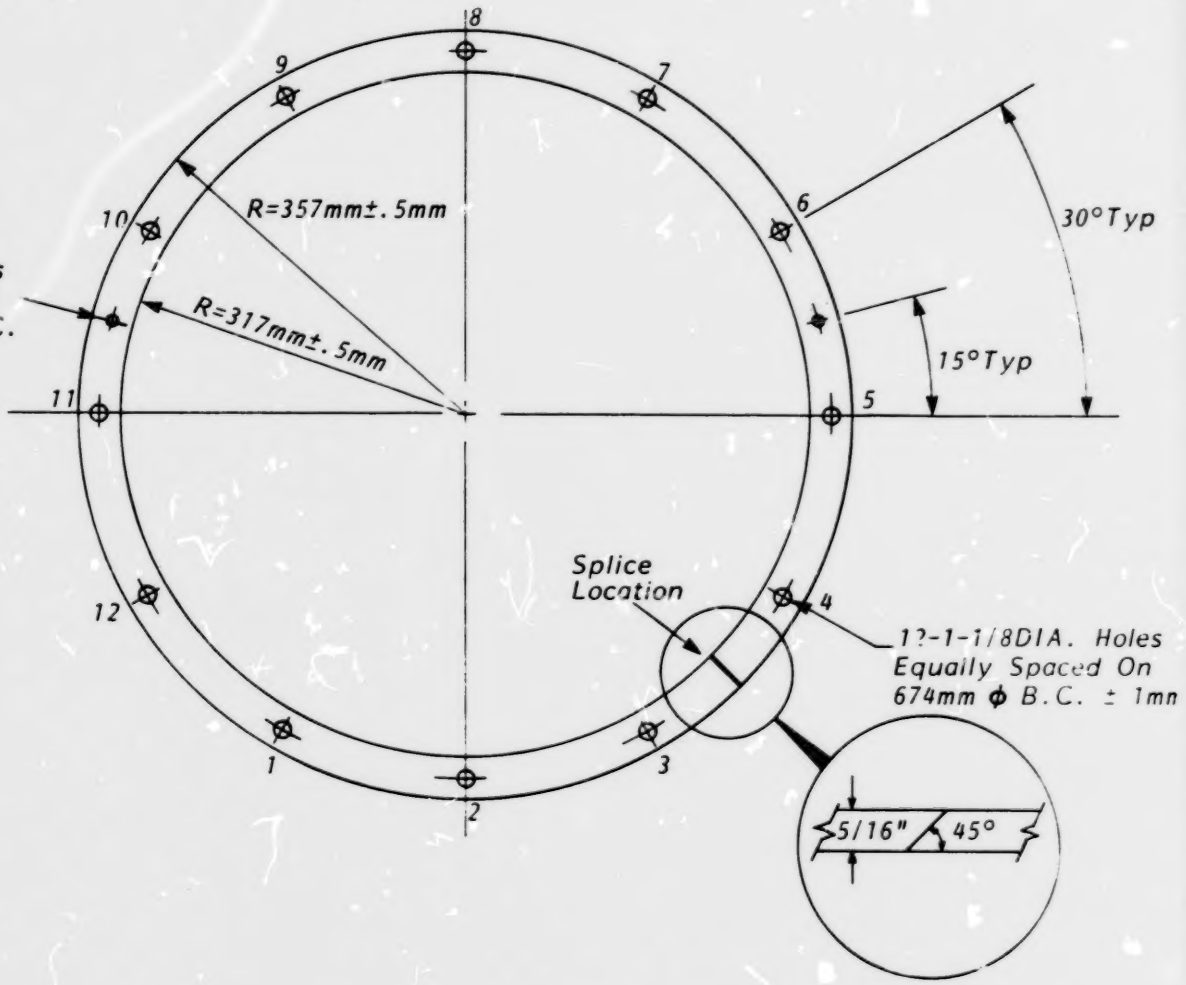

Material : Solid Silicone Rubber

Thickness : 5/16"

Side View

FIGURE 11

SPLICED SOLID SILICONE RUBBER GASKET

The overflow of silicone cement was not removed immediately, since the integrity of the newly formed joint would have been disturbed. It was allowed to solidify and an attempt was later made to remove as much of the overflow as possible. The gasket surface, however, was not restored to its original smoothness and thus remained slightly rough. This roughness made it more difficult to obtain a good seal between the rig and gasket which resulted in a slightly higher leak rate. The roughness, however, had no apparent effect on the outcome of the hydrostatic pressure test. During regular gasket production it can be expected that a procedure will be developed to produce smoother splices.

It should be noted that prior to the helium leak test, some high vacuum grease was placed over the rougher splice. The vacuum grease played the role of filling in any possible leak paths caused by the overflow of silicone cement.
No vacuum grease was used prior to the hydrostatic pressure test.

5.0 CONCLUSIONS

The silicone closed-cell sponge gasket that was tested failed the 24 hour hydrostatic pressure test. It is believed that the gasket leaked because the 15 psi sealing pressure was not enough to flatten the gasket's stiffer dimpled backing. As a result good contact between rig and gasket was never obtained, allowing water to leak out. It is also felt that a contributing factor may have been that the gasket width between the bolt holes and the gasket's inner diameter was too small. The gasket material is designed to have closed cells, but given the narrowness of the area, a leak path may have existed from cell to cell. It would be desirable to have several cell thicknesses in this area to ensure that no leak path exists. In addition, this part of the gasket is also the weakest, and so it is possible that the water pressure may have deformed the gasket. If the width of this area were to be increased and the dimples eliminated, the gasket may perform better.

It should be noted that the silicone closed-cell sponge gasket actually used on the D_2O container does not have a dimpled backing. The gasket tested was made by the manufacturer with the dimpled backing for some unknown reason. As a result, the comments regarding the dimples will not apply to the actual D_2O gasket.

Solid silicone rubber was found to be much more suitable as a gasket material, as higher sealing pressures (164 psi) were obtained. The gasket made from this material passed both the hydrostatic pressure and helium leak tests confirming its suitability. It was also found to exhibit good compressibility characteristics as shown in the following table.

TABLE 1

Solid Silicone Rubber Compressibility Table

Compressive Load (lbs)	Compressibility (%)
146	1
200	4
500	5

With respect to cutting and splicing the silicone rubber gasket, it was found that this process had little effect on the short term performance of the gasket. The gasket successfully passed the hydrostatic pressure test and saw a slight increase of 2.0×10^{-5} std cc/sec in the helium leak rate. This increase was apparently caused by surface roughness created by overflow of silicone cement during the splicing process.

The effect of not using high vacuum grease over the rough spliced area, on the helium leak rate, was not determined. The long term effect of the splice on the gasket performance was also not determined.

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APPENDIX A

CALCULATIONS

GASKET SEALING PRESSURES

1.0 SILICONE CLOSED CELL SPONGE GASKET

This gasket had a thickness of 3/8" (0.375 in). The gasket seat in the test rig (Figure 1) is 7.1 mm (0.2795 in) deep. The difference between these two values is the total height which the gasket was squeezed in sealing the test rig.

$$0.375 - 0.2795 = 0.0955 \text{ inch}$$

From the load displacement curve (Figure 7) a displacement of 0.0955 inch requires a compressive load of 15 lbs. Since the specimen's cross sectional area was 1 in^2 then the sealing pressure was 15 psi.

2.0 SOLID SILICONE RUBBER GASKET

Using the same procedure outlined above:

Gasket thickness: 5/16" (0.3125 in) Figure 9
Gasket seat depth: 7.1 mm (0.2795 in) Figure 1

$$\text{Gasket displacement} = 0.3125 - 0.2795$$
$$= 0.033 \text{ in}$$

From Figure 8 this displacement corresponds to a sealing pressure of 164 psi.

COMPRESSIBILITY OF SILICONE RUBBER SAMPLE (0.25 in Thick)

The load displacement curves in Figure 10 were obtained using the specimen restraining jig. From the top curve (maximum loading = 200 lbs) the maximum displacement obtained at 200 lbs was 0.0192 in. However, there was an air gap of 0.010 in between the cross heads of the machine and the sampling jig. The total displacement of the silicone sample was, therefore, only 0.0192 - 0.010 = 0.0092 in.

$$\text{The volume that was displaced} = 0.0092 \text{ in} \times 1 \text{ in}^2$$
$$= 0.0092 \text{ in}^3$$

Note: Due to the geometry of the gasket specimen (see Figure 5) A portion of the displaced volume was used to fill in voids. The volume of the voids must be subtracted from the total displaced volume.

Assuming void is parabolic in shape.

and $h = 0.002$)
$a = 0.125$) measured

then

$$\text{Area of Void} = \frac{4ah}{3} = 0.0003 \text{ in}^2$$

$$\text{Volume of Void} = 0.0003 \text{ in}^2 \times \text{circumference}$$
$$= 0.0003 \text{ in}^2 \times \pi \times 1.1284$$
$$= 0.0011 \text{ in}^3$$

The actual displaced volume is 0.0092 - 0.0011 in
$= 0.0081 \text{ in}^3$

$$\text{This represents } \frac{0.0081^3}{(0.25 - 0.0011 \text{ in}^3)} = \frac{0.0081}{0.2491} = 3.25\%$$

The volumetric displacement of 0.0081 in^3 represents 3.25% of the specimen's original unloaded volume.

The same calculations were performed for the 500 lb loading yielding.

Displaced Volume = 0.0236 - 0.010 = 0.0136 in^3
Actual Displaced Volume = 0.0136 - 0.0011 = 0.0125 in^3
This represents $\frac{0.0125}{0.2489}$ = 5.0% of original
unloaded volume

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